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Impacts of city size change and industrial structure change on CO_2 emissions in Chinese cities

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ABSTRACT

The cities' area accounts for only 2% of the world's surface area, but the cities' population accounts for 50% of the total population and produces more than 80% of the total CO_2 emissions. So the cities have a key position in solving the global challenge of climate change. In order to estimate the impacts of city size change and industrial structure change on CO_2 emissions, based on the background, the data availability of the CO_2 emissions per person, the economic scale, the size of land use, the industrial concentration degree and the industrial structure change in 50 cities in different sizes (the population size between 0.5 million and 1 million, 1–2 million, 2–4 million and more than 4 million) from 2005 to 2014, the paper studies the impact of the city size change and the industrial structure change on CO_2 emissions. The results show that the increase in the sizes of cities can bring in the rise of CO_2 emissions and the impacts on CO_2 emissions in different city sizes are significant. Meanwhile, both industrial agglomeration and industrial structure change have a significant role in the CO_2 emissions reduction. The paper finds out that (1) the medium-sized cities produce relatively fewer CO_2 emissions than the smaller cities and the bigger cities. As smaller cities are not conducive to save land and also can't play the externalities of industry agglomeration, leading to the reduction in energy efficiency. Bigger cities may produce all kinds of city diseases. The medium-sized cities with the population of 1 million and 2 million can have relatively higher energy efficiency and fewer city diseases, which may produce lower CO_2 emissions. (2) economic growth can increase CO_2 emissions.(3) the industrial structure change has effects on CO_2 emissions, and CO_2 emissions from the secondary industry are the largest in the three industries. So, the government should reasonably give priority development of medium-sized cities with the population between 1 million and 2 million, and adjust energy consumption structure and the industrial structure to give priority to the tertiary industry to reduce CO_2 emissions in China's cities.

1. Introduction

Climate change is the common challenge which the human faces in the 21st century. It has become an international trend to make global cooperation in climate change and promote green low carbon development. As a responsible big developing country, China will not only regard to promote low carbon development as a positive international obligation, but also see it as a basic requirement to realize the sustainable development of its own.

The State Council in China came up with the goal to reduce the emission intensity of economic growth by 40%–45% below 2005 levels by 2020 in 2009 (The State Council, 2009). China also raised its goal to achieve its carbon emissions peak in around 2030, with the intention of peaking earlier by 2030. In order to solve the increasing city's CO_2 emissions in the process of the urbanization, the climate low carbon city initiated (China Daily, 2014).

Along with economic growth, the large-scale urbanization brings in its high-speed development. Urbanization is the result of the rapid development of economy, society and also the further power of them. CO_2 emissions from cities accounted for more than 80% in the total CO_2 emissions in China (Mi et al., 2017a,b). During

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the period from 1998 to 2015, the number of the resident population in the cities increased from 170 million to 770 million. The urbanization rate increased from 33.4% to 56.2%, which increased by 1.27% per year. And the number of the cities increased to 653 (National Bureau of Statistics of China, 2016).

The cities are the consumption concentration of energy and resources, and are also the concentration of CO_2 emissions. The area of the cities only accounted for 2% of the world's surface area, but their population accounted for 50% of the total population and CO_2 emissions accounted for about 80% of the total emissions (Gu and Guo, 2012; The United Nations Human Settlements Program, 2011). The cities lie in a key position in solving the global challenge of climate change.

Therefore, based on the background and the availability of data from 2005 to 2014, this paper selects 50 cities in different sizes (the population size between 0.5 million and 1 million, 1–2 million, 2–4 million and more than 4 million) to analysis the influence of the city size change and industrial structure change on CO_2 emissions. The contributions of the paper are in the following: (1) From the data and the guidelines for national greenhouse gas inventories, the paper calculates CO_2 emissions in 50 cities. (2) On the influence of city size change on CO_2 emissions, the paper not only focuses on the change of the economic growth on CO_2 emissions, but also focuses on the change of the population size and land use on CO_2 emissions. (3) The paper takes into account the impact of industrial agglomeration on CO_2 emissions. The previous studies mainly considered the impact of the economic growth, population size and land use on CO_2 emissions, less research focused on the impact of industrial agglomeration on CO_2 emissions. On the one hand, with the expansion of the city scale, scale economics can promote industrial agglomeration; on the other hand, with the expansion of city scale and the increase of CO_2 emissions, the agglomeration of industries will be restrained.

2. Literature review

2.1. The influence of city size on CO_2 emissions

City size mainly refers to the number and level of the material and elements which the city aggregates in a certain space, which includes economy size, population size and land use size (Liu and Zhou, 2006). The influence of city size on CO_2 emissions is mainly analyzed from these three aspects.

(1) Economic growth and CO_2 emissions in the cities

In terms of a single city and multiple cities, some scholars in China and other countries studied the economic growth and CO_2 emissions. Taking the five provincial capital areas which located in northwest area, Ren et al. (2006) found that the influence of economic development on climate change was not completely in line with Kuznets curve's characters. Liu and He (2015), Wang (2017) studied the relationship between economic growth and CO_2 emissions and found that different degrees of economic growth could produce different CO_2 emissions. Economic growth also brings industrial agglomeration change in the cities, thus, with the cities' sizes becoming bigger, industrial agglomeration may have impact on CO_2 emissions. With panel data model and panel data of 31 provinces, cities and districts in 1999–2010, Li and Zhang (2013) studied the influence of industrial agglomeration on environmental pollution. And they found that industrial agglomeration had positive externality. Liu and Song (2013) indicated that industrial agglomeration could effectively improve environment. With provincial panel data in 1999–2012, Yuan and Xie (2015) found an upside-down "U" type relationship between industrial agglomeration and environmental pollution. Based on panel data from 2005 to 2014 in China, Qu et al. (2017) considered that industrial agglomeration could promote the CO_2 emissions efficiency and CO_2 emissions. Using econometric model, Chen et al. (2018) explored the effects of industrial agglomeration on CO_2 emissions and found industrial agglomeration brought in CO_2 emissions.

(2) Population size change and CO_2 emissions in the cities

Population urbanization is closely related to CO_2 emissions and some scholars believe that the population urbanization can lead to the increasing in CO_2 emissions. Ehrlich and Ehrlich (1970) established the IPAT model for the first time to reflect the impacts of population changes on environmental pressure. The innovation of this model was to link environmental impact and population, GDP per capita and technology development level together. Dietz and Rosa (1994) established a random form of IPAT, which may be used to analyze the impacts of various driving factors on environmental pressure through the stochastic regression analysis of population, economy and technology, and it was called STIRPAT model for short. Murtaugh and Schlax (2009) deduced the impacts of population changes on CO_2 emissions and found that population changes would have an impact on economic activity and CO_2 emissions. Qu and Jiang (2012) analyzed the influence of regional population size and structure on CO_2 emissions, adopting the panel data and STIRPAT model of 30 provinces from 1997 to 2009. The studies showed that the population at work had significant positive effects on CO_2 emissions. Wang et al. (2016) studied the relationship among urbanization, population and CO_2 emissions, adopting the panel data model and data of Southeast Asian countries from 1980 to 2009. It was found that each 1% increasing for city population would bring in 0.2% increasing for CO_2 emissions. Li et al. (2017) considered that the optimal city size for CO_2 emissions reduction was about 1.78 million people.

(3) The change of land use and CO_2 emissions in the cities

The process of urbanization is also a process of land use change. Along with the advancement of urbanization, the impact of land use change on CO_2 emissions can't be ignored. The change of the way in land use is one of the important factors in climate changes, former studies have shown that the construction land expansion, unused land reclamation and the change of wetland degradation have increased CO_2 emissions to a great extent (Watson et al., 2000). Houghton et al. (1983, 1991, 1999) established a model to calculate CO_2 emissions caused by global land use change. Based on the different scales of countries or regions, Nowak and Crane (2002) studied the carbon storage of city trees and found that city trees played an important role in CO_2 concentration reduction. Based on the population density distribution models, Svirejeva and Schellnhuber (2008) calculated CO_2 emissions caused by the expanding of city size in 8 regions of the world from 1980 to 2005, and found that CO_2 emissions caused by the city size expansion was about 11.25 million tons. Houghton et al. (2012) believed that the amount of CO_2 emissions caused by land use change accounted for 12.5% between 1990 and 2010. Heald and Spracklen (2015) believed that changes in land use could lead to climate and air quality change. Zhang (2015), Wu et al. (2017) all believed that there was a close relationship between the process of urbanization and land use change. Wu et al. (2017) found land use change brought out different proportion change of CO_2 emissions.

2.2. The influence of industrial structure change on CO_2 emissions

Industrial structure plays a vital role in the beginning of the

origin of the cities. There are much research on the effects of the industrial structure on CO_2 emissions. The scholars generally adopts structural decomposition analysis, the input and output model and econometric analysis method et al. to study on the influence of industrial structure change on CO_2 emissions.

Using structural decomposition analysis and the input and output model, Liaskas et al. (2000), Schipper et al. (2001), Okushima and Tamura (2007), Llop (2007) all recognized that industrial structure would reduce CO_2 emissions. Using structural decomposition analysis and environmental input–output, Mi et al. (2017a,b) deemed that production structure and consumption patterns caused a 2.6% and 1.3% decrease in China's carbon emissions from 2010 to 2012 and the emissions embodied in China's foreign exports also declined from 2007 to 2012. Mi et al. (2015) and Shan et al. (2017) both considered that reforming the industrial structure was a useful way to control CO_2 emissions.

There are many scholars to study on the influence of industrial structure change on CO_2 emissions with the method of econometric analysis. Zheng and Liu (2011), Wang (2014), Yuan et al. (2016) and Liu et al. (2017) all adopted different econometric analysis method to explore the relationship between the industrial structure and CO_2 emissions and found out that industrial structure change had a close relationship to CO_2 emissions.

2.3. Literature summary

(1) Generally, previous literature mainly focused on the change effect of population size or land use on CO_2 emissions, which was not comprehensive. Because city size change can bring the change of economic growth, population size and the way change of land use at the same time in the process of urbanization. And economic growth can also bring industrial agglomeration. Based on this background, in order to better describe the influence of the city size change on CO_2 emissions, this paper considered the three aspects together, including the impact of economy size change, population size change and land use size change on CO_2 emissions.

(2) On the impact of industrial structure on CO_2 emissions, it can be seen that previous scholars mainly employed certain cities or provincial capital cities. Few scholars studied it from the different city sizes. Thus, research on the effect of industrial structure in different city sizes need to supplement.

3. Methods and data

3.1. The effect models of city size, industrial agglomeration change on CO_2 emissions

(1) The basic model

Previous studies show that the impact of the city size change on CO_2 emissions is not linear, which may be U shape curve, inverted U shape curve, N shape curve or inverted N shape curve.

1) U shape curve. In the process of the urbanization, CO_2 emissions will decrease with the increase of the city size; while with further increase of the city size, CO_2 emissions will rise year by year.
2) Inverted U shape curve. In the process of the urbanization, with the increase of the city scale, CO_2 emissions will increase too; while with further increase of the city scale, CO_2 emissions will decrease year by year.
3) N shape curve. In the process of the urbanization, the impact on CO_2 emissions of the city size change begins to show the inverted U shape curve. While after reaching a certain level, the curve will show a positive relationship. That is, the increase of the city size can lead to the rise of CO_2 emissions.
4) Inverted N shape curve. In the process of the urbanization, the impact of the city size change on CO_2 emissions begins to show the U shape curve. While after reaching a certain level, the curve will show a reverse trend. That is, the increase of the city size can lead to the decrease of CO_2 emissions.

First, CO_2 emissions are calculated according to the IPCC method (IPCC, 2006).

$$C = \sum E_i{*}\rho_i \tag{1}$$

C is CO_2 emissions, E_i is the i-th energy consumption, and ρ_i is the emission factor of the i-th energy.

Then, this paper builds the basic model as follows.

$$C_{it} = \alpha + a_1CS_{it} + a_2CS_{it}^2 + a_3CS_{it}^3 + b_1IA_{it} + b_2IA_{it}^2 + b_3IA_{it}^3 + \delta Z + \varepsilon \tag{2}$$

Using the logarithm variables to replace the original variable in the equation (2), the equation (3) can be gained in the following. .

$$lnC_{it} = \alpha + a_iln(CS_{it}) + b_iln(IA_{it}) + \delta Z + \varepsilon \tag{3}$$

Where, i and t indicates different cities and years. C_{it} are the CO_2 emissions per capita. A_{it} are GDP per capita. CS_{it} show the city size. IA_{it} express industrial agglomeration. Z is the control variable. α is the constant term. a_i, b_i, δ are the variable coefficients. And ε is the error term.

(2) The effect model of city size on CO_2 emissions

There is an interaction relationship between city size and industrial agglomeration. The interaction has a certain influence on energy consumption and energy use efficiency in the cities, which will affect CO_2 emissions. In order to study on the influence of the city size change on CO_2 emissions, based on the former literature, this paper builds the different models and makes the following hypotheses.

H1. In the process of city size expansion, the expansion of city size can increase CO_2 emissions, while the improvement of industrial agglomeration can reduce the CO_2 emissions in the cities.

H2. The larger the city sizes are, the higher industrial agglomeration degrees are. The reduction effect of CO_2 emissions in larger city sizes is relatively bigger than that in smaller city sizes.

H3. Increasing the degree of industrial agglomeration can improve energy efficiency and thus it can reduce the CO_2 emissions.

To test whether H1 is logical, this paper introduces the cross terms of industrial agglomeration degrees (IA) and population sizes (P), the model is built in the following.

$$lnC_{it} = \alpha + a_iln(CS_{it}) + b_iln(IA_{it}) + \theta_1 \ln(IA \cdot P) + \delta Z + \varepsilon \tag{4}$$

If H1 is logical, namely $\theta_1 < 0$.

In order to test whether H2 is logical, the model is built in the following.

$$\ln(C_{it}) = \alpha + a_iln(CS_{it}) + b_iln(IA_{it}) + \theta_2 \ln\left(\sum_{n=1}^{4} CS_nIA\right) + \delta Z + \varepsilon \tag{5}$$

As city sizes are divided into five types, the paper introduces

four cross terms of virtual variables and industry agglomeration degrees to analysis the effect of the industrial agglomeration on CO_2 emissions in different kinds of cities. If θ_2 is not significant, then H2 isn't logical.

For the sake of examining whether H3 is logical, the paper introduces cross terms of city size, industry agglomeration degree and energy use efficiency in the model.

$$\ln(C_{it}) = \alpha + a_i ln(CS_{it}) + b_i ln(IA_{it}) + \theta_3 ln \sum_{n=1}^{4} CS_n \cdot IA \cdot \mathrm{CD} + \gamma Z + \varepsilon \tag{6}$$

If θ_3 is significant, H3 is logical.

3.2. The effect model of industrial structure on CO_2 emissions

(1) In order to analysis the effect of industrial structure change on CO_2 emissions, based on the model of Talukdar and Meisner (2001), the paper builds the model in the following.

$$\ln(C_{it}) = \alpha + a_i ln(A_{it}) + b_i ln(PI_{it}) + c_i ln(SI_{it}) + d_i ln(FDI_{it}) + \varepsilon \tag{7}$$

where C_{it} are the CO_2 emissions per capita. A_{it} are GDP per capita. PI_{it} are the primary industry, SI_{it} are the secondary industry, and FDI_{it} are foreign direct investment.

(2) In order to examine the effect on CO_2 emissions of industrial structure change, taking the reference to Tan and Zhang (2011), the paper brings in the integrated industrial structure index (IISI) instead of the primary industry index and the secondary industry index. IISI includes the indexes of the industry output value structure and employment structure. The industry output value structure indexes are measured by the proportion of the three industrial structures accounting for GDP. The employment structure indexes are calculated by the proportion of the employment in the three industrial structures accounting for the total employment. The model is set up in the below.

$$\ln(C_{it}) = \alpha + a_i ln(A_{it}) + b_i ln(IISI_{it}) + c_i ln(FDI_{it}) + \varepsilon \tag{8}$$

3.3. Index description and data sources

(1) CO_2 emissions per capita

Some cities have the data of energy consumption intensity and the data all come from their provinces or cities statistical yearbooks. Energy consumption in some cities can be calculated according to the data of energy consumption intensity. Then CO_2 emissions for some cities can be calculated based on the guidelines for national greenhouse gas inventories (IPCC, 2006). For other cities, they have the data of all kinds of energy consumption, then CO_2 emission factors for different kinds of energy (Xiamen Public Energy-saving Service Network, 2012) are used to calculate CO_2 emissions for these cities based on the guidelines for national greenhouse gas inventories (IPCC, 2006) directly. All the data of the cities' population are from their provinces or cities statistical yearbooks. Then CO_2 emissions per capita can be estimated.

(2) City size

The indexes of city sizes cover economy size, population size and land use size. Economic size is the cities' GDP. Population size refers to the number of city population, which is expressed by the total number at the end of the year. The land use size refers to the land area which has been built up.

(3) Industrial agglomeration

Industrial agglomeration mainly refers to the high concentration of the pillar industry and its related industries. As the meaning of industrial agglomeration is similar to specialization, the paper selects the city specialization level to measure industrial agglomeration degree. The paper chooses economic density and employment density to measure the industrial agglomeration degree. Economic density refers to GDP per unit area. Employment density refers to the ratio of the employment in the pillar industry accounting for the total employment.

(4) Industrial structure

Synthesizing previous study, the paper chooses the ratios of the output values in the primary industry and the secondary industry (PI1, SI1) accounting for GDP and the ratios of the employment figures in the primary industry and the secondary industry (PI2, SI2) accounting for total employment figures. IISI is measured by the indexes of the proportion in the three industrial structures accounting for GDP, employment structure and the proportion of the employment in the three industrial structures accounting for the total employment.

(5) Data sources

According to the data availability, 50 cities in different sizes are selected. The data from 2005 to 2014 are mainly from China city statistical yearbooks, the provinces' yearbooks and China energy statistical yearbooks. The 50 cities in the different sizes are exhibited in Fig. 1.

The variable descriptions of 50 cities in the different sizes are shown in Table 1, including a dependent variable and ten independent variables.

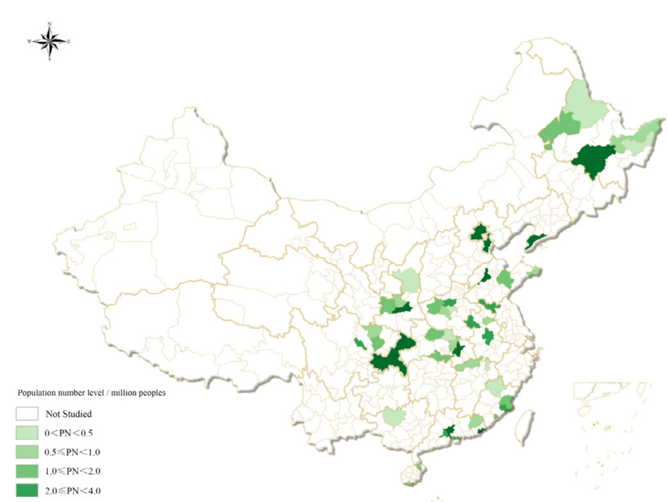

Fig. 1. 50 cities of different sizes.

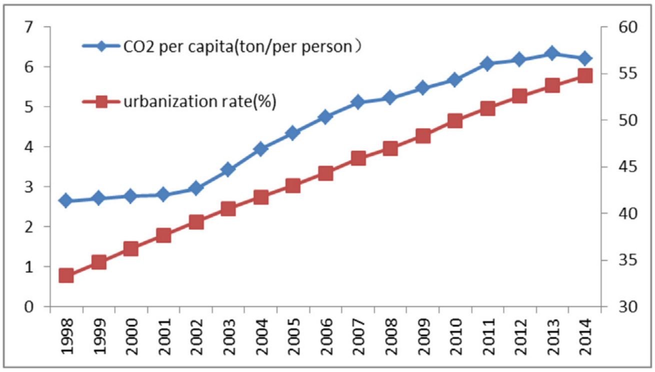

Fig. 2. The relationship between CO_2 per capita and urbanization rate from 1998 to 2014 (source: National Bureau of Statistics of China, 2016).

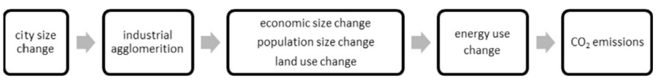

Fig. 3. The influence mechanism of city size change on CO_2 emissions.

Table 1
Variable descriptions of 50 cities.

variable		symbol	unit
dependent variable	CO_2 emissions per capita	C	kg/per person
independent variable	PN < 0.5	CS1	Ten thousand
	$0.5 \leq$ PN < 1	CS2	Ten thousand
	$1 \leq$ PN < 2	CS3	Ten thousand
	$2 \leq$ PN < 4	CS4	Ten thousand
	$4 \leq$ PN	CS5	Ten thousand
	economic size	A	Ten thousand yuan
	population size	PS	Ten thousand
	land use size	LUS	Square kilometers
	industrial agglomeration	IA	–
	energy use efficiency	EUR	%

4. Results and discussion

4.1. The relationship between city size change and CO_2 emissions

(1) The influence mechanism of city size change on CO_2 emissions

With the changes of production and lifestyle, population explosion also has many impacts on energy utilization, technology and trade, which leads to the increase of energy consumption. In addition, urbanization also brings prosperous to those products, such as iron, steel, copper, aluminum, cement, glass and other goods. As energy and resources which used to make these products are extremely huge, thus CO_2 emissions increase, too.

From Fig. 2, it could be seen that there were rising trends for CO_2 emissions per capita and urbanization rate from 1998 to 2014, which were consistent with the results of Lin and Liu (2010), Sun and Li (2010), Xiao (2011), Zhu et al. (2016). CO_2 emissions in the cities are the main parts in China's CO_2 emissions (Song and Xu, 2011; Li, 2015). Rapid urbanization had a great influence on CO_2 emissions (Li, 2011). The influence mechanism of city size change on CO_2 emissions was shown in Fig. 3.

(2) The influence results of city size change on CO_2 emissions

According to the models built in the above, the data and the five different classifications, the influence results of city size change on CO_2 emissions were demonstrated in Table 2 in the following. After testing, these three hypotheses were found to be held in China's cities.

As shown in Table 2, the increase in the sizes of cities could bring in the rise of CO_2 emissions. The impacts on CO_2 emissions in different city sizes were significant. For CS1, CS2, CS3, CS4, CS5, when there was a 1% rise in population size, there would bring in the increase of CO_2 emissions by 0.76%, 0.45%, 0.38%, 0.85% and 0.59% respectively. It could also be seen from the results, there was a smallest increase in CO_2 emissions in CS3.

At the same time, in the three models, the impacts on CO_2 emissions of economic size in different city sizes were significant. When economic size increases by 1%, there will bring in the increase of CO_2 emissions by 0.31%–0.43%. And the impacts on CO_2 emissions of population size in different city sizes are also significant. If population size increases by 1%, there will be CO_2 emissions increase by 0.281%–0.892%. The impacts on CO_2 emissions of land use are significant, too. When the increase of land use rises by 1%, there will be 0.58% increase of CO_2 emissions.

Thus, in the process of urbanization, it is different for the influence of different city size on CO_2 emissions. The population size between 1 million and 2 million is more suitable for China's low-carbon path, which is consistent with Zhang's opinion (2013).

(3) The influence results of industrial agglomeration change on CO_2 emissions

If by sharing the public infrastructure and other factors, industrial agglomeration can realize energy saving and utilization efficiently, then the degree of industrial agglomeration can be useful in increasing economic growth and reducing CO_2 emissions at the same time. However, if by increasing the cities' investment, then this kind of economic growth is unsustainable and may lead to higher CO_2 emissions.

As shown in Table 3, constant improving in industrial agglomeration has a significant role in the CO_2 emissions reduction. When industrial agglomeration rises by 1%, there will be a decline for CO_2 emissions by 0.894%–0.979%. As improving in industrial agglomeration can improve energy efficiency and public infrastructure in the cities and thus can help to reduce CO_2 emissions. When energy efficiency rises by 1%, there will be a decline for CO_2 emissions by 1.154%–1.165%.

However, in different sizes, industrial concentration degree is also different, which may reduce different CO_2 emissions. The larger cities sizes are, the more CO_2 emissions industrial agglomeration can reduce. The smaller cities sizes are, the fewer CO_2 emissions industrial agglomeration can reduce. The results test that H2 exists in these 50 cities. And the results are consistent with the viewpoints of Qu et al. (2017) and Chen et al. (2018), too.

Table 2
The influence results of city size change on CO_2 emissions.

variable	Model 1	Model 2	Model 3
lnCS1	-0.76^{***} (0.024)	−0.14 (0.033)	0.75 (0.049)
lnCS2	−0.06 (0.019)	-0.45^{*} (0.029)	−0.17 (0.041)
lnCS3	−0.117 (0.036)	-0.38^{**} (0.043)	−0.72 (0.059)
lnCS4	−0.46 (0.035)	-0.85^{*} (0.065)	−0.112 (0.101)
lnCS5	−0.12 (0.053)	-0.59^{*} (0.069)	−0.64 (0.125)
lnA	0.43^{***} (0.004)	0.39^{***} (0.007)	0.31^{***} (0.014)
lnPS	0.281^{**} (0.119)	0.892^{***} (0.176)	0.831^{***} (0.282)
lnLUS	-0.058^{***} (0.023)	−0.017 (0.035)	0.075 (0.049)
constant	-5.26^{***} (0.475)	−0.529 (0.529)	6.348^{***} (0.589)

Notes: ***, **, * indicates they are significant in the confidence levels of 1%, 5%, 10% respectively.

Table 3
The influence results of industrial agglomeration change on CO_2 emissions.

variable	Model 1	Model 2	Model 3
lnCS1			−0.135* (0.089)
lnCS2			−0.039 (0.054)
lnCS3			0.089 (0.028)
lnCS4			0.089 (0.027)
lnCS5			0.076 (0.024)
lnA		0.898*** (0.018)	0.898*** (0.021)
lnPS	0.893*** (0.029)		
lnLUS	−0.026* (0.014)	0.007 (0.048)	0.021 (0.058)
IA	−8.943*** (0.293)	−9.787*** (0.211)	−9.674*** (0.211)
IA*EUR	−1.54*** (0.311)	−1.644*** (0.023)	−1.646*** (0.024)
constant	−1.324*** (0.219)	7.979*** (0.328)	7.869*** (0.232)

Notes: ***, **, * indicates they are significant in the confidence levels of 1%, 5%, 10% respectively.

4.2. *The relationship between industrial structure change and CO_2 emissions*

(1) The influence mechanism of industrial structure change on CO_2 emissions

The acceleration development of urbanization improves the level of productivity and industrial structure also has a lot of changes. As can be seen from Fig. 5, basically, the proportion of output values in the primary industry accounting for GDP was in a decline trend since 1978, falling by 18.9%; the proportion of output values in the secondary industry accounting for GDP was also in a decline trend, dropping by 5.2%; however, the proportion of output values in the tertiary industry accounting for GDP was in upward trend, increasing by 24.2% (Fig. 4).

From Fig. 5 in the below, it could be seen that the proportion of employment in the primary industry accounting for the total employment fell by 41%, while the proportion of employment in the secondary industry and the tertiary industry accounting for the total employment rose by 12.6% and 28.4%. The speeding up of urbanization led to more and more people migrating from the villages to the cities.

Industrial structure change can change the energy consumption, which can effect CO_2 emissions. The influence mechanism of industrial structure change on CO_2 emissions is demonstrated in the following (Fig. 6).

The first industry structural adjustment can have an impact on the management of land use, production mode and production structure, which will change the total amount of energy consumption and affect the level of CO_2 emissions. The secondary industry structural adjustment can have an impact on the scale of production, the internal structure and the new energy industry investment, which will change the structure of energy

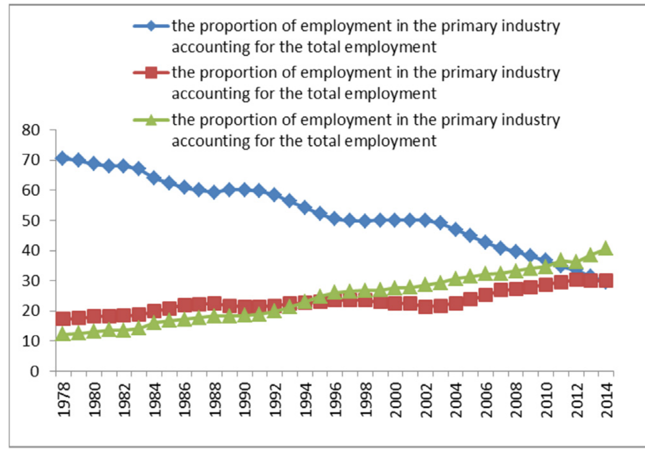

Fig. 5. The proportion of employment in the three industries accounting for the total employment (%) (source: National Bureau of Statistics of China, 2016).

Fig. 6. The influence mechanism of industrial structure change on CO_2 emissions.

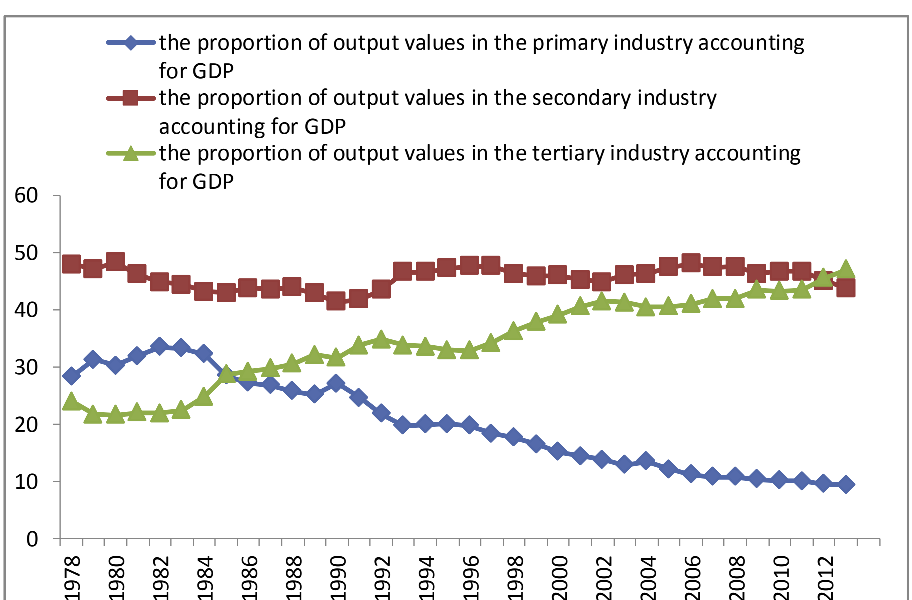

Fig. 4. The proportion of output values in the three industries accounting for GDP (%) (source: National Bureau of Statistics of China, 2016).

consumption and energy efficiency of the industry. These changes affect the level of CO_2 emissions. In the process of the tertiary industry structural adjustment, the changes of industrial structure will have an impact on the scale of production. And it can guide the direction of the industrial structure to adjust to high added value, low energy consumption, and thus affect the level of CO_2 emissions.

(2) The influence results of industry structure change on CO_2 emissions

First, the paper tests the influence results with the change of PI1, SI1, PI2, SI2 on CO_2 emissions (as shown in model 1 in Table 4) by controlling the factor of economic growth. It can be seen from the regression results in model 1 in Table 4, economic size has also impacts on CO_2 emissions, and the impacts are significant. When economic size industry changes by 1%, it may bring in the increase by 0.734% for CO_2 emissions. It can be seen that the city's CO_2 emissions have correlation with PI1 and SI1. While, the effects of PI2 and SI2 change on CO_2 emissions are not significant. When the output values in the primary industry accounting for GDP change by 1%, it may bring in CO_2 emissions increase by 0.146%, however, it isn't significant. When the output values in the secondary industry accounting for GDP change by 1%, it may bring in CO_2 emissions increasing between 0.159%, and it is significant. FDI change also has impacts on CO_2 emissions, but the impacts are very small. If FDI change by 1%, it may bring in CO_2 emissions increase by 0.0055%.

Then, the influence results with the industry structure change (IISI instead of PI1, SI1, PI2, SI2) on CO_2 emissions are shown in model 2 in Table 4. The regression results show that there is a great correlation between the cities' CO_2 emissions and the industrial structure. Changes in the size of the industrial structure will still lead to a significant change in CO_2 emissions. If industry structure changes by 1%, it may bring in CO_2 emissions increase between 0.082%, and it is significant.

From the analysis above, it can be seen clearly that industrial structure change has an impact on CO_2 emissions, and the industrial structure change is an important driving factors of cities' CO_2 emissions, which are consistent with the perspectives of Mi et al. (2015) and Shan et al. (2017).

5. Conclusions and policy implications

5.1. Conclusions

Using the data from 2005 to 2014 in China's 50 different cities, the paper makes three hypotheses and constructs the models of city size change and industrial structure change on CO_2 emissions. After testing, these hypotheses are found to be suitable for China and the conclusions are made in the following.

Table 4
The influence results of industry structure change on CO_2 emissions.

Variable	Model 1	Model 2
A	0.734*** (8.41)	0.239*** (3.34)
PI1	0.146 (1.31)	
SI1	0.159*** (6.15)	
PI2	0.17 (0.13)	
SI2	0.65 (6.34)	
FDI	0.0055* (2.29)	0.0086* (1.95)
IISI		0.082*** (7.33)
constant	−1.525*** (0.367)	−0.957** (0.538)

Notes: ***, **, * indicates they are significant in the confidence levels of 1%, 5%, 10% respectively.

(1) The cities with the population size between 1 million and 2 million produce relatively lower CO_2 emissions than those smaller cities and bigger cities.

Smaller cities are not conducive to save land and also can't play the externalities of industry agglomeration, which may lead to the decrease in energy efficiency. Due to large size, bigger cities may produce all kinds of city diseases. The medium-sized cities with the population size between 1 million can have relatively higher energy efficiency than smaller cities and fewer city diseases than bigger cities, so they may produce lower CO_2 emissions.

(2) Economic growth has effects on CO_2 emissions.

The impact of economic growth on CO_2 emissions depends on the degree of its dependence on different sources of energy. Since the Reform and Opening-up in 1978, China has entered into the industrialization stage. With a rapid development of industrialization and its dominant position, a continuous demand for fossil fuels has increased. At the same time, energy efficiency isn't high and the utilization of clean energy is limited. Therefore, CO_2 emissions increased substantially.

(3) The industrial structure change affects CO_2 emissions, and it has the biggest influence on CO_2 emissions in the secondary industry.

From the angle of cities, the industrial structure change affects CO_2 emissions, and the influence in the secondary industry is the biggest among the three industries. Secondary industry produces the biggest CO_2 emissions. CO_2 emissions from the primary industry and the tertiary industry are relatively fewer.

5.2. Policy implications

According to the conclusions obtained in the paper, three policy implications are put forward in the following.

(1) The government should reasonably give priority development of medium-sized cities with the population between 1 million and 2 million. As the medium-sized cities with the population size between 1 million and 2 million produce relatively lower CO_2 emissions, so the government should plan the city size to achieve an optimal level to reduce CO_2 emissions in the process of urbanization.
(2) The government should adjust energy consumption structure to reduce the dependence on fossil fuels. At the same time, coal liquefaction, coal gasification and other energy-saving technologies should be employed. And new energy, clean energy should be vigorously developed.
(3) Adjusting the industrial structure to give priority to the tertiary industry is another useful way to reduce CO_2 emissions in China's cities. The government should use economic and administrative means to integrate the industry resources, improve industrial equipment energy consumption and emission standards, eliminate backward production capacity and limit high carbon industry development to reduce CO_2 emissions from the secondary industry.

While, there are also some shortcomings in this paper. First, although the methodology used in the paper is more convenient to operate and it can measure the correlation degrees among each factor and the degree of regression fit accurately, it also has the disadvantage that the selection of the driving factors is chosen according to the literature and the data availability. Second, only 50

cities are studied in the paper. In the future, we can use free CO_2 emissions data in cities level in the China Emission Accounts and Datasets (CEADs) to calculate CO_2 emissions in Chinese more cities, so as to measure the impacts of city size change and industrial structure change on CO_2 emissions.

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